"Substitute" Specification

Devices for correcting a signal derived from a detector

Priority Claim

TECHNICAL FIELD

[0002]   The present invention concerns the analysis of a stream of particles received by a particle detector during a given time period, in particular with the aim of measuring the corresponding incident energy.

BACKGROUND

[0003]   An important cause of the limited quality of signal processing is the background noise that is always present in the output current of the detector. This background noise comprises at least two components. The first component is known as the "dark current",in particular, the fluctuating current of thermal origin emitted by the detector, even when it is not receiving photons; the value of this current depends on the temperature of the detector and on its bias state. The second component is the "transient decay current", in particular, the fluctuating current that is manifested for a certain time after the reception of a photon by the detector; in detectors using semiconductor materials, the transient decay current is primarily due to crystal defects in these materials.

[0004]   Consider the consequences of this background noise for the accuracy of measurements effected by prior art devices operating by integration.

[0005]   In these devices, the output current of the detector is integrated directly, and a quantity deemed to represent the effect of the background noise is then subtracted from the charge calculated in this way to obtain a value representative of the incident energy proper. This conventional approach is probably motivated by the need to take account of the totality of the incident energy, including low values thereof, whence the absence of any current processing device on the input side of the integrator. However, as explained above, it is not possible to assign an accurate value to the background noise, in particular because of thermal drift, thermal fluctuations and the transient decay phenomenon. Because of this, prior art incident energy measurements are subject to errors, the magnitude of which is difficult to estimate.

SUMMARY

[0006]   The detectors considered in the context of the present invention are known in the art, whether they are of unitary or matrix type, and regardless of the semiconductor or other materials from which they are constituted. For example, the detector may use a CdZnTe material and be exposed to X-rays. The output signals of these detectors may be either electrical currents or of a physical kind that can be converted into an electrical current in a manner known in the art. It will simply be assumed that the reception of a particle by the detector triggers an output signal having the form of a pulse of a certain width and the maximum amplitude of which is representative of the energy of that particle.

[0007]   The invention further concerns measuring systems operating by integration, by means of which the total energy of the radiation received by the detector is measured over a predetermined time period by integrating the current derived from the detector over that time period.

[0008]   The invention applies to any field in which the

analysis of a stream of particles may be beneficial, for example, when the particles are photons, in radiology, fluoroscopy or imaging. It is particularly adapted to fields in which there is a need for a signal processing method which, although being of high quality (in the sense that said method provides very accurate measurements of the stream), uses for this purpose a compact device; this is the case in particular when the device consists of a matrix of pixels rather than a single detector (pixel), as the size of the electronics is then limited by the pitch of the pixels.

[0009]   The invention therefore consists in relatively compact devices capable of reducing, in particle stream measurements, the portion caused by drift and fluctuations of the background noise present in the signals derived from a detector, in particular when the stream of particles is relatively weak.

[0010]   The invention therefore provides, firstly, a device for processing a signal (i) derived from a particle detector, said device comprising an integrator for measuring the total charge transported by a signal (i_2) feeding said integrator for a predetermined time interval. According to the invention, this device further comprises a plurality of units for receiving the signal (i) derived from said detector, for reducing the background noise present in this signal (i) and for producing said signal (i_2).

[0011]   The inventors have realized that modern signal detection means are inherently low-noise devices of sufficient accuracy for it to be feasible to envisage placing signal correction units on the upstream side of the integrator, rather than on its downstream side, without in so doing losing any significant portion of the information contained in this signal or generating significant unwanted components in this signal. Appropriate units may then be chosen to attenuate, or even eliminate, particular components of the signal constituting part of the background noise.

[0012]   According to particular features of the invention, one of said units is adapted to eliminate the DC component of the background noise that consists essentially of the darkness current, thermal drift of which may be assumed to be sufficiently slow for it to be valid to consider the darkness current as a DC component. This unit could comprise a capacitor in series, for example.

[0013]   According to further particular characteristics of the invention, one of said units is adapted to reduce the fluctuating component of the background noise that consists essentially of the darkness current fluctuations and the transient decay current.

[0014]   According to even more particular features of the invention, said unit for reducing the fluctuating component of the background noise comprises:

        a converter for associating with an input current an output voltage (e), followed by

        a threshold trigger for allowing current to pass when said voltage (e) exceeds a first predetermined threshold value (ε_1) and for preventing current from passing when the voltage (e) falls below a second predetermined threshold value (ε_2), followed by

        a converter for associating an input voltage with an output current.

[0015]   To give a more concrete idea of what is being explained, it is assumed here that the voltage pulse e(f) takes positive values; it is a simple matter to transpose the features of the invention to a situation in which these values are negative.

[0016]   Thus the device of the invention totally circumvents the electrical charge transported by the signal between the pulses, with the result that the background noise fluctuations have an effect only during the short duration of the pulses, during which the measurements are effected. This significantly improves the quality of the measurements compared to prior art

devices.

[0017]   The invention secondly provides a device for
processing signals produced by a set of particle detectors,
said device being noteworthy in that at least one of those
signals is processed by means of a device as briefly described
hereinabove.

[0018]   It will be noted that the various devices of the
invention may easily be implemented by means of standard
miniaturized semiconductor components, as will be demonstrated
in the detailed description hereinafter, with the result that
these devices are of compact size and low unit cost.

[0019]   Finally, the invention is directed to diverse
apparatus for analyzing a stream of particles including a
device of the kind briefly described hereinabove.

[0020]   Other aspects and advantages of the invention will
become apparent on reading the following detailed description
of particular embodiments of the invention provided by way of
non-limiting example. The description refers to the appended
drawings, in which:

BRIEF DESCRIPTION OF THE DRAWING

[0021]   FIG. 1 represents a conventional device for
processing a signal derived from a particle detector,

[0022]   FIG. 2 represents one embodiment of a device of the
invention for processing a signal derived from a particle
detector,

[0023]   FIG. 3 represents one embodiment of the FIG. 2
device adapted to reduce the fluctuating component of the
background noise, and

[0024]   FIG. 4 shows how the signal derived from the
integrator varies as a function of time when using the device
represented in FIG. 3.

DETAILED DESCRIPTION

[0025]   In the following description, reference will be made to the detection of "photons" (in particular, to measuring characteristics of electromagnetic radiation), but it is clear that the invention is totally independent of the nature of the particles detected.

[0026]   FIG. 1 represents a conventional device for processing a signal derived from a particle detector 1 which may use a CdZnTe material, be supplied with power by a high-tension supply HT and be used to measure X-rays, for example.

[0027]   In response to the arrival of a photon at its receiving surface, the detector 1 emits a current pulse i. The current i is processed by an integrator 2 to produce an output signal s that represents the total electrical charge conveyed by the current i during the time t.

[0028]   The integrator 2 may comprise an amplifier A_2 and a capacitor C_2 in parallel, for example. A switch SW_2 controlled by a logic unit 3 reinitializes the integration process at predetermined time intervals T.

[0029]   FIG. 2 represents a device 100 for processing a signal derived from a particle detector 1 constituting one embodiment of the invention. The detector 1 is similar to that from FIG. 1. This device 100 comprises an integrator 2 and a logic unit 3 which are also similar to the corresponding units from FIG. 1.

[0030]   In accordance with the invention, units 4 and 5 inserted between the detector 1 and the integrator 2 are adapted to receive the current i derived from the detector 1, reduce the background noise present in that current i and produce the current i_2 feeding the integrator 2.

[0031]   In this embodiment, a bias resistor R_p inserted between the detector 1 and the high-tension supply HT stabilizes the output voltage of the detector 1.

[0032]   The current i derived from the detector 1 enters a

unit 4 adapted to eliminate a DC component of the background noise. In this embodiment, this unit 4 is simply a capacitor C_1.

[0033]   The output current i_1 of the unit 4 then enters a unit 5 adapted to reduce a fluctuating component of the background noise.

[0034]   Finally, the output current i_2 of this unit 5 feeds the integrator 2, from which finally emerges the signal $\underline{s}(t)$ "corrected" in accordance with the invention.

[0035]   FIG. 3 represents one embodiment of the unit 5 from FIG. 2.

[0036]   In this embodiment, the current signal $i_1(t)$ derived from the unit 4 is converted into a voltage signal $e(t)$ in the converter 6. In this embodiment, the converter 6 consists of an amplifier A_1 in parallel with a resistor R_1.

[0037]   An alternative to this is to add a further component in parallel consisting of a capacitor (not shown), which converts the current amplifier A_1 into an amplifier of the electrical charges derived from the detector 1. It is then necessary to add a band-pass filter (not shown) in series with this combination so as to revert to a voltage that images the current derived from the detector 1. Like the above embodiment, this variant reduces the contribution of the background noise to the measurements, but with a better signal/noise ratio, in exchange for a slightly more complex configuration.

[0038]   The unit 5 then comprises a threshold trigger 7, represented diagrammatically here in the form of a switch SW_1 controlled by a logic unit 8, and which could in practice comprise a comparator, for example.

[0039]   The threshold trigger 7 allows current to pass when the voltage $e(t)$ exceeds a first predetermined threshold value ε_1 and prevents current from passing when the voltage $e(t)$ falls below a second predetermined threshold value ε_2. Said thresholds ε_1 and ε_2 are adjusted as a function of the

intended application so that their value is sufficiently low to allow most of the current to pass during pulses resulting from the impact of a particle on the detector and sufficiently high to prevent the current from passing when the latter contains only the fluctuations of the darkness current and/or the transient decay current.

[0040]   The unit 5 finally comprises a converter 9 that associates a current i_2 with the voltage signal at the output of the threshold trigger 7. In this embodiment, the converter 9 simply consists of a resistor R_2.

[0041]   FIG. 4 shows the behavior of the signals e and $\underline{s}$ as a function of time t.

[0042]   The function e(t) features a succession of pulses above the idle voltage (here taken as the origin), between $t = t_0$ and $t = t_1$, and then between $t = t_2$ and $t = t_3$, and so on; these pulses are naturally the translation via the units 4 and 6 of the pulses present in the current i. The curve of the voltage e(t) shown in FIG. 4 shows the irregularities caused by thermal fluctuations and the transient decay phenomenon; however, in practice, the relative amplitude of these irregularities is generally not as great as that shown here to explain the invention more clearly.

[0043]   In this embodiment, the following condition applies for the triggering threshold of the threshold trigger 7: $\varepsilon_1 = \varepsilon_2 \equiv \varepsilon$.

[0044]   The curve representing the output signal $\underline{s}$(t) of the device 100 of the invention thus shows the integration of the charges conveyed by the current i minus the DC component of the background noise in particular.

[0045]   Observe that this signal $\underline{s}$(t) remains constant in the time intervals situated between the pulses generated by the impact of a photon on the detector, such as the time interval between $t = t_1$ and $t = t_2$. Accordingly, thanks to the invention, the total charge measured is completely free of the background noise present in the time intervals between the

pulses.

[0046]   Secondly, the signal $\underline{s}$(t) features rising portions in the time intervals corresponding to the impact of a photon on the detector, such as the time interval between $t = t_0$ and $t = t_1$ or between $t = t_2$ and $t = t_3$. The total charge measured is free of the DC component of the background noise present during the pulses, in the same way as it is eliminated in the time intervals between the pulses. Although it is true that the device of the invention does not eliminate the electrical charge caused by the fluctuating component of the background noise during the pulses, it is clear that this contribution to the total charge decreases as the total duration of the pulses relative to the total measuring time T decreases. The invention is therefore all the more advantageous the weaker the stream of particles, but it will further be noted that when the stream of particles concerned is strong, the total charge measured is high, and the fluctuating component of the current derived from the detector is then negligible anyway.

[0047]   The present invention is not limited to the embodiments described hereinabove: in fact, the person skilled in the art may well conceive of diverse variants of the invention without departing from the scope of the following claims. For example, it is clear that instead of placing the unit 4 on the input side of the unit 5, between the detector 1 and the integrator 2, these units may equally well be in the opposite order, subject to appropriate adjustment of the thresholds ε_1 and ε_2.